# DISK-AVERAGED SYNTHETIC SPECTRA OF TERRESTRIAL PLANETS

Final Report

JPL Task 1034

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## A. OBJECTIVES

With the recent discovery of a multitude of planets orbiting other stars, NASA is committed to developing the advanced instrumentation and observing techniques required to characterize other worlds and search for remote-sensing signatures of life. To drive and optimize the development of instruments for characterization of the state of habitation of other worlds, and to understand remotely-sensed information from extrasolar planets, we need to undertake modeling work to better understand the information available to us in disk-averaged spectra of terrestrial planets.

As part of understanding how to characterize extrasolar terrestrial planets, this task seeks to explore what can be learned about a planet's surface and atmospheric properties from disk-averaged spectra at a number of spectral resolutions. This task concentrates on synthetic spectra for Mars, and is part of a larger effort which uses a radiative transfer model and atmospheric and surface data for Earth, Mars, Venus and Titan to generate spatially-resolved synthetic spectra for a range of illumination conditions (phase angles) and viewing geometries. These spectra will then be spatially averaged, and processed with an observing system simulation tool that simulates the spectral and spatial resolution, signal levels, noise sources and other properties of planned extrasolar terrestrial planet observing systems, including nulling interferometers and coronographs.

This task was funded as Dr. Meadows' Lew Allen Award, and was used to fund two SURF students this summer, in addition to covering a small fraction of Dr. Meadows' time to supervise them. In addition to the science goals, it was important to introduce and train these two young scientists to the field of astrobiology, and to hopefully fuel their continued interest in both science and the new field of astrobiology.

## B. PROGRESS AND RESULTS

### 1. Science Data

Two students were trained to use the Spectral Mapping Atmospheric Radiative Transfer Model (SMART; Meadows and Crisp, 1996), including all the ancillary programs and input files, and taught to generate synthetic spectra for Mars. Using their newly acquired skills, they were able to gather available data on atmospheric properties

and surface albedo for Mars, and use this data to generate synthetic spectra for Mars for a given solar illumination, but for arbitrary viewing angle.
In addition to generating the planetary spectra, they also developed a model architecture for the resultant planet simulation model that takes into account user-specified pixellization of the planet. The resultant model, which we completed for a single Mars "day," consists of a selection, pixellization and interpolation architecture, and draws upon a pre-calculated database of synthetic spectra for a range of viewing angles, solar illumination and surface albedos to populate the pixel resolution and viewing geometry specified by the model's user.

This work was written up as a Caltech SURF report and will form the basis for a science poster at the General Meeting of the NASA Astrobiology Institute, and for a paper to be submitted to the Journal *Astrobiology*.

Current work on this model includes generating further "days" within the model, to allow us to generate planetary lightcurves for arbitrary viewing angle, and as seen by astronomical instrumentation.

2. Other Results

In addition to creation of the first cut of this model, we were able to introduce two young scientists to the field of astrobiology. Both enjoyed their work immensely, and are interested in future SURF opportunities on this project. Perhaps most significantly, William has chosen to work in the field of extrasolar terrestrial planet characterization for a reading course term paper at Caltech, and has chosen to be mentored in this further effort by Dr. Meadows.

## C. SIGNIFICANCE OF RESULTS

This task developed a proof-of-concept model for a much larger task which seeks to understand the appearance of extrasolar terrestrial planets when viewed in the disk-average, and from arbitrary viewing angle. The techniques developed under this task will now be used and expanded for the larger task of modeling Venus, Earth and Titan. In addition to its science goals of understanding detectability of characteristics for planets that we have data for, this task sets up a validation model for subsequent tasks of a larger project which involves generating disk-averaged synthetic spectra for extrasolar terrestrial planets.

The results indicate that such modeling is feasible on relatively short time scales, and should provide a versatile model which can be used to address the detectability of planetary characteristics in the disk-averaged spectra that will be available to extrasolar planet detection and characterization missions such as TPF.

## D. FINANCIAL STATUS

The total funding for this task was $25,000, all of which will be expended by the task end date, which is March ’03.

## E. PERSONNEL

This Task funded Caltech/JPL Summer Undergraduate Research Fellowships for Heather Snively of the University of Santa Cruz, and William Fong of Caltech.

## F. PUBLICATIONS AND PRESENTATIONS

[1] This work will provide the basis of a conference poster for the General Meeting of the NASA Astrobiology Institute in Feb 2003, and will also provide the basis for the paper on the planetary models that is to be submitted to *Astrobiology* in early 2003.

## G. REFERENCES

[1] V. Meadows, and D. Crisp, “Ground-Based Near-Infrared Observations of the Venus Nightside: The Thermal Structure and Water Abundance Near the Surface,” *JGR-Planets,* 101, 1996, 4595-4622.